Protocols for Mapping Soil Salinity (and Other Soil Properties) at Field Scale Using EMI EC_a-Directed Soil Sampling

D.L. Corwin[1] and S.M. Lesch[2]

[1]USDA-ARS, U.S. Salinity Laboratory, Riverside, CA
[2]University of California, Riverside, CA

The Problem

Soil salinity detrimentally impacts crop yield by osmotic effects, toxic ion effects, and effects on soil tilth and permeability. FAO (2002) estimates that worldwide 20-30 million ha of land are seriously salt affected with 0.25-0.5 million ha lost from production yearly from salt accumulation. Yet, no accurate inventory and monitoring of soil salinity is available due to the complex spatial and temporal nature of salinity. Traditional point measurements are impractical and of limited value when attempting to map salinity at field scales and larger spatial extents. The USDA-ARS Salinity Laboratory has recently developed protocols for characterizing the spatial variability of soil salinity (and other soil properties) at field- and landscape scales using electromagnetic induction (EMI) to measure apparent soil electrical conductivity (EC_a), a physico-chemical property influenced by salinity, texture, organic matter, water content, bulk density, and temperature. These protocols provide a practical and efficient means of measuring, monitoring, and assessing field- and landscape-scale soil salinity.

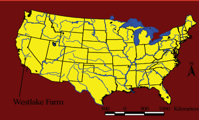
Objectives

1. Present protocols for mapping soil salinity (and other soil properties) at field scale using an intensive spatial survey of EC_a to direct soil sampling.
2. Apply/evaluate protocols to a case study of salt accumulation and soil quality assessment on a drainage water reuse site in California's San Joaquin Valley.

Eight Step Protocols[1]

1. Site description and EC_a survey design
2. EC_a data collection with mobile GPS-based EMI equipment
3. Develop a model- (e.g., response surface sample design) or design-based (e.g., unsupervised classification) soil sampling strategy from geo-referenced EC_a data
4. Conduct soil core sampling at specified sites designated by the sample design
5. Laboratory analysis of appropriate soil physical and chemical properties defined by project objectives
6. Develop a stochastic and/or deterministic calibration of EC_a to salinity (EC_e) or to other soil properties (e.g., water content, texture, etc.)
7. Spatial statistical analysis to determine the soil properties influencing EC_a
   (a) perform a basic statistical analysis of physical and chemical data by depth increment and by composite depth over the depth of measurement of EC_a
   (b) determine the correlation between EC_a and physical and chemical soil properties by composite depth over the depth of measurement of EC_a
8. GIS database development and graphic display of spatial distribution of soil properties

Case Study Site



Study Site: A 32.4-ha field located on the westside of the San Joaquin Valley in central California. The soil is part of the Lethent clay loam series, a fine, montmorillonitic, thermic, Typic Natrargid.

Materials & Methods

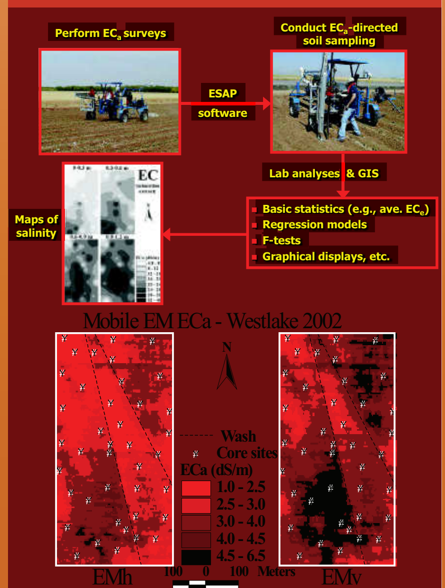
Intensive EC_a survey: The EC_a survey followed the detailed survey protocols pertaining to soil quality assessment as described by Corwin and Lesch (2005)[1]. Mobile dual-dipole EM38 equipment was used to obtain 22,177 geo-referenced measurements of EC_a across the 32.4-ha study site. Measurements of EC_a were taken in the horizontal (EM_h) and vertical (EM_v) coil configurations. The survey was performed 8-12 April 2002.

Soil core sampling: The soil core sampling design was established from the EC_a survey measurements using ESAP software, which located 40 soil core sites. The 40 sites were chosen to satisfy the following three criteria: (i) to represent about 95% of the observed range in the geometric mean EM data, (ii) to represent about 95% of the observed range in the EMI profile ratio data, and (iii) to be spatially distributed to reflect the spatial variability of the EC_a measurements and to minimize clustering. Soil cores were taken at 0.3-m increments to a depth of 1.2 m.

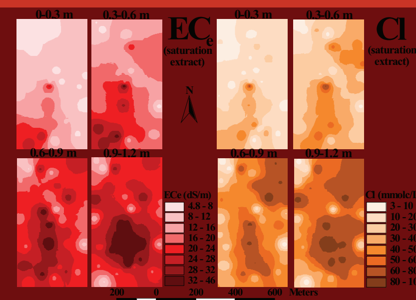
Measured physicochemical soil properties: Each 0.3-m increment soil sample was analyzed for total C and N, EC_e; pH_e; anions (HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}) and cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in the saturation extract; trace elements (B, Se, As, Mo) in the saturation extract; $CaCO_3$; gypsum; cation exchange capacity (CEC); exchangeable Na^+, K^+, Mg^{2+}, and Ca^{2+}; exchangeable sodium percentage (ESP); and sodium adsorption ratio (SAR). The soil samples were also analyzed for soil physical properties including saturation percentage (SP), volumetric water content (θ_v), bulk density (ρ_b), and clay content.

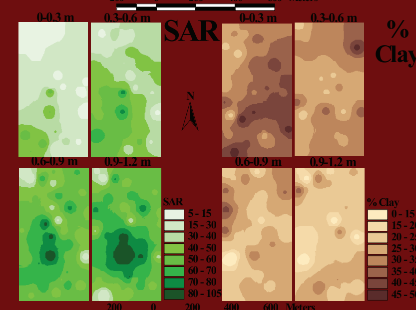
GIS: ArcView 3.3 was used to store, manipulate, and display the spatial data.

EC_a Survey Approach & Results



EC_a-Directed Soil Sampling Results





Correlations Between Soil Properties and EC_a

θ_v ($m^3\ m^{-3}$)	0.63**
EC_e ($dS\ m^{-1}$)	0.84**
Anions in saturation extract (mmolc/L):	
Cl^-	0.81**
NO_3^-	0.34*
SO_4^{--}	0.79**
Cations in saturation extract (mmolc/L):	
Na^+	0.83**
K^+	0.71**
Mg^{++}	0.61**
SAR	0.82**
B ($mg\ L^{-1}$)	0.40**
Se ($\mu g\ L^{-1}$)	0.51**
Mo ($\mu g\ L^{-1}$)	0.40**
Inorganic C (g/kg)	-0.47**
Organic C (g/kg)	-0.47**

*Significant at $P \leq 0.05$ level. **Significant at $P \leq 0.01$ level. † N=31. ‡ N=41. Measured over 0-0.6 m

Conclusions

- EC_a-directed sampling was able to spatially characterize the following soil properties: salinity (EC_e), θ_v, % clay, anions (Cl^-, NO_3^-, SO_4^{--}), cations (Na^+, K^+, Mg^{++}), SAR, B, Se, Mo, and inorganic and organic C.
- The outlined protocols provide a means of characterizing the spatial variability of soil physical and chemical properties for use in site-specific crop management (Corwin et al., 2003a)[2], landscape-scale modeling of non-point source pollutants in the vadose zone (Corwin et al., 1999)[3], soil quality assessment (Corwin et al., 2003b)[4], and assessment of spatio-temporal management-induced change (Corwin et al., 2005)[5].

References

1. Corwin, D.L., and S.M. Lesch. 2005. Characterizing soil spatial variability with apparent soil electrical conductivity. I. Survey protocols. Comput. Electron. Agric. 46(1-3):103-134.
2. Corwin, D.L., S.M. Lesch, P.J. Shouse, R. Soppe, amd J.E. Ayars. 2003a. Identifying soil properties that influence cotton yield using soil sampling directed by apparent soil electrical conductivity. Agron. J. 46:517-520.
3. Corwin, D.L., M.L.K. Carrillo, P.J. Vaughan, J.D. Rhoades, and D.G. Cone. 1999. Evaluation of GIS-linked model of salt loading to groundwater. J. Environ. Qual. 28:471-480.
4. Corwin, D.L., S.R. Kaffka, J.W. Hopmans, Y. Mori, S.M. Lesch, and J.D. Oster. 2003b. Assessment and field-scale mapping of soil quality properties of a saline-sodic soil. Geoderma 114(3-4):231-259.
5. Corwin, D.L., S.M. Lesch, J.D. Oster, and S.R. Kaffka. 2006. Monitoring management-induced spatio-temporal changes in soil quality with soil sampling directed by apparent soil electrical conductivity. Geoderma 131:369-387.

POSTER NUMBER 15